

CLIMATIC ASSESSMENT OF A 580-YEAR *CHAMAECYPARIS LAWSONIANA* (PORT ORFORD CEDAR) TREE-RING CHRONOLOGY IN THE SISKIYOU MOUNTAINS, USA

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ABSTRACT

Tree-ring data from *Chamaecyparis lawsoniana* (A. Murr.) Parl. (Port Orford cedar; Cupressaceae) were used to create a standardized chronology, assess the local, limiting factors on radial growth, and investigate the extent of a unique climatic event. We produced a 580-year tree-ring chronology (A.D. 1420 to 2000) from a large number of cedars ($n = 1537$) sampled in one 37 km² area in the Siskiyou Mountains of southwestern Oregon and northern California. This chronology represents an area with few long-term climatic studies and a species with no dendrochronological data. We found radial growth to be positively correlated with year-round soil moisture conditions, specifically with cool, wet conditions in summer and warm, wet conditions in winter. The year 1739 stood out as a climatic pointer year with the smallest ring width index for the entire chronology and anatomically distinctive damage to the latewood of 1738 and earlywood of 1739. This pointer year was consistently identified across watersheds, topographic position (e.g., streamside, hillslope), and the range of the cedar, corresponding to an extreme, single-year drought occurring throughout the Pacific Northwest.

Key Words: *Chamaecyparis lawsoniana*, Port Orford cedar, Siskiyou Mountains, tree-ring analysis, 1739, drought.

Tree-ring records have long been accepted as an effective proxy method to examine paleoclimatic conditions (Douglass 1920). Because the width of annual growth rings varies with the surrounding climatic conditions (e.g., temperature and precipitation), a temporal record of past climatic variability is established showing trends as well as specific events (e.g., severe single-year droughts). Tree-ring chronologies can indicate limiting growth factors for a particular species (i.e., the principle of sensitivity), provide insight into long-term climatic conditions, and identify the basic biology (e.g., physiology, autecology) of particular tree species (Fritts 1976).

This study focused on the tree-ring record of *Chamaecyparis lawsoniana* (A. Murr.) Parl. (Port Orford cedar; Cupressaceae), a conifer endemic to southwestern Oregon and northern California (Fig. 1). The chronology presented here represents cedars located in the Siskiyou Mountains, a region containing one of the most diverse conifer forests in the world (Whittaker 1960). Our chronology establishes important baseline climatic information given the paucity of long-term climatic data for this region and the absence of Port Orford cedar tree-ring chronologies.

The ecology and conservation of Port Orford cedar has become an increasingly important topic as additional portions of the cedar's range continue to be infected by a fatal, non-native root pathogen,

Phytophthora lateralis. The source pathogen, first detected in the cedar's range in 1952, spreads downstream in flowing water and also along road systems when spores are dispersed from mud on vehicles. Because Port Orford cedar is a commercially valuable conifer and a dominant species in many parts of its range, its continued loss has caused significant economic and ecological impacts to the Pacific Northwest (Hansen et al. 2000). As part of an earlier study, we and our colleagues (Jules et al. 2002) assessed the spread dynamics of this pathogen by using dendrochronological techniques as a tool to reconstruct the infection history of cedars, resulting in tree-ring data from 1537 cedars.

The large dataset resulting from this previous study yielded strong correlations among trees and a record covering a long time span (A.D. 1361 to present). Thus, the tree-ring data allowed for the establishment of a standardized chronology and assessment of Port Orford cedar's radial growth patterns compared to corresponding climatic data. For example, many of the tree cores showed physical damage occurring after the latewood of 1738 and during the springwood of 1739, indicating an extreme, single-year event (Fig. 2). This damage coincided with the year 1739 being the smallest growth ring of the entire 580-year chronology.

To summarize, our objectives were to: 1) develop a standardized chronology for Port Orford cedar in the Siskiyou Mountains 2) determine which climatic factors the radial growth patterns best represent and 3) investigate the occurrence of the unique climatic event.

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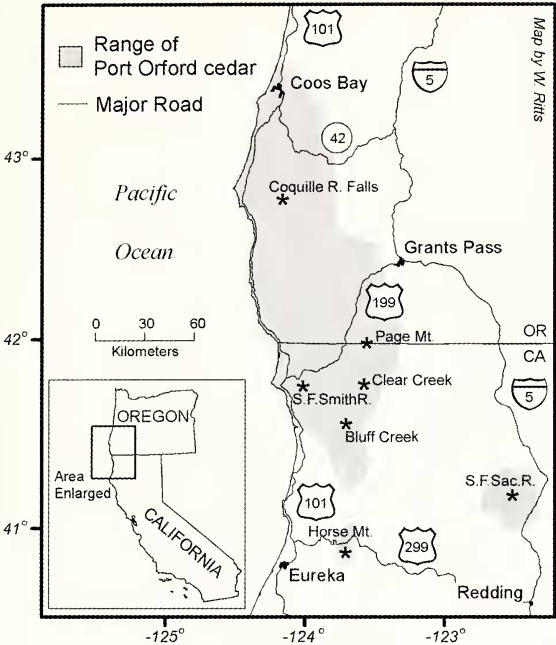


FIG. 1. Approximate range of Port Orford cedar and locations of sites where increment cores were sampled. See Table 1 for details.

METHODS

Study Organism and Study Area

The geographic range of Port Orford cedar extends from the northern end of the California Coast Ranges to the uplifted marine terraces and Coast Ranges near Coos Bay, Oregon, and inland along the drainages of the Klamath and Siskiyou Mountains (Zobel et al. 1985; Fig. 1). This region has cool, wet winters and warm, dry summers that limit the cedar to areas that maintain significant soil moisture year-round (Zobel and Hawk 1980). Accordingly, over much of its range, the cedar is re-

stricted to riparian areas, wetlands, and mesic uplands.

Our study area for the chronology includes 37 km² near Page Mountain situated on the Oregon/California border and within the Siskiyou National Forest. We sampled individual cedars from five watersheds within the study area: Little Elder Creek, Elder Creek, Page Creek, Dunn Creek, and Poker Creek. For many trees sampled, the topographic position of the cedar was recorded as one of six types (active channel, streambank, floodplain, high floodplain, terrace, or hillslope). Trees within ~20 m of the streams were sampled, accounting for ~80 to 95% of the cedar's population at our study site. This sampling was random with regards to age, size, and height of trees (Kauffman 2003).

Tree-Ring Data and Chronology

In the Page Mtn. study area, 3350 cores from 1537 cedars were sampled and crossdated. All the cores in this study were sampled using increment borers and prepared using standard dendrochronological methods (Stokes and Smiley 1968). We used a combination of visual techniques and the software COFECHA for crossdating (Holmes 1983). Cores were measured to 0.001 mm precision using a Velmex measuring system. Only series with strong correlations were added to the original, master chronology that had a total of 965 series from 593 cedars.

The software ARSTAN was used to standardize the chronology (Cook 1985). The ARSTAN standardization process removed the non-climatic growth trend from each series and collapsed all the series into a single numeric representation of the tree-ring pattern based around an index of 1.0. For the standardized ARSTAN chronology, 65 series from 61 cedars were chosen based on the criteria of high COFECHA correlation coefficients, long time span coverage, and simple detrending options (negative exponential curve, linear regression, or

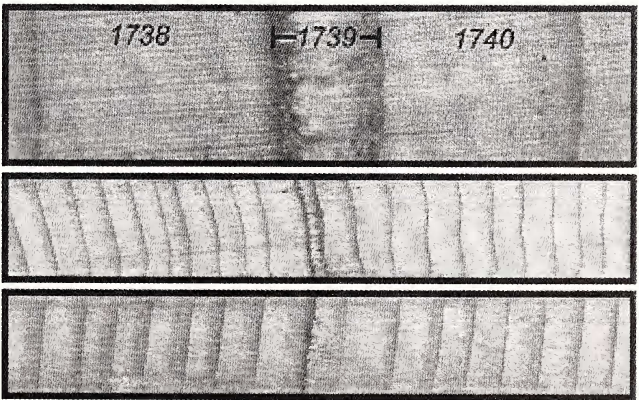


FIG. 2. Examples of the anatomical damage to the latewood 1738 and earlywood 1739 found in Port Orford cedar tree cores. Contact authors for higher resolution image.

TABLE 1. LOCATION AND CORRESPONDING SAMPLE SIZE OF INDIVIDUAL CEDARS FOR ALL STUDY SITES.

Site	Latitude (°N)	Longitude (°W)	Number of cedars sampled
Page Mountain	42.00	123.34	271
Coquille River Falls	42.43	124.02	13
South Fork Smith River	41.46	124.00	4
Bluff Creek at Fish Lake	41.16	123.41	5
Clear Creek	41.45	123.38	13
South Fork Sacramento River	41.15	122.26	16
Horse Mountain	40.50	123.44	3

horizontal line through the mean). We selected the conservative approaches of single detrending and the standard (STD) version of the ARSTAN generated chronology for our analyses.

Climate Data

Historical monthly records from A.D. 1895 to 2000 for temperature, precipitation, and Palmer Drought Severity Index (PDSI) were obtained from the U.S. National Climatic Data Center (NCDC). The PDSI reflects long-term soil moisture availability and incorporates the effects of temperature, precipitation, and evapotranspiration (Palmer 1965). For each climatic factor, we chose Oregon Climate Division 3 because it best captures the conditions of our study site and uses measurements from several stations in southwestern Oregon. Regional data from several weather stations reduce local anomalies from single stations and often provide more reliable data than single stations for the investigation of tree-ring chronologies (Blasing et al. 1981).

Pearson correlation coefficients were used to assess climatic influences on radial growth. While evaluating such correlations, it is important to consider that climatic conditions in the previous year(s) may affect the growth of the current year's ring (Fritts 1976). Thus, although the growing season of Port Orford cedar is approximately from April to September, the conditions from November of year ($t - 2$) to the current September (year t) were also considered. In addition, correlations were calculated between the ring width index and the cumulative average of the climatic factors from the previous September to the current September to allow for an assessment of conditions on an annual scale. The software program NCSS 2001 was used for all correlation tests (Hintze 2001).

Extreme Event Indicators

For each cedar that was old enough to capture the 1739 growth ring, the presence or absence of physical damage was recorded and the growth index was calculated. Physical damage was evident in the form of abnormal cell structure, discoloration, and often resin formation to the latewood of 1738 and earlywood of 1739. The growth index

was defined as the ratio of the width of the 1739 ring to the average width of the five rings before and after 1739. This index allowed for a size comparison of a particular year with the surrounding years experiencing similar longer-term conditions. A similar technique was recently developed by Knapp et al. (2002) and called a climatic pointer year index. To assess whether the growth index differed between geomorphologic positions, we used a Kruskal-Wallis test. To test whether physical damage was found more frequently on some geomorphologies, we used a chi-square analysis.

Regional Sampling

To investigate the spatial extent of the 1739 extreme climatic event, we sampled cedars at six sites across its range in addition to Page Mtn. (Table 1, Fig. 1). Regional site selection was principally dictated by finding areas that were accessible and sufficiently old to include the 1739 growth ring. Since most of the northern extent of the cedar's range is on private land, these areas were difficult to access and also had few old trees, resulting in limited sampling there. Sampling at the regional sites was less intensive than the sampling at the Page Mtn. site since we were only sampling large individuals that show the 1739 year. Evidence of the extreme event would indicate it affected the area; however, given the smaller sample sizes, absence of the indicators would not preclude that the event affected the area.

RESULTS

Chronology

The overall COFECHA series correlation for the initial 965 series in the master chronology was $r = 0.509$ (critical $r = 0.328$ where $P \leq 0.01$). The best 65 of these series were used to develop the ARSTAN standardized chronology. The Expressed Population Signal (EPS) for the ARSTAN chronology was 0.94, where a value of 0.85 is generally regarded as the level of acceptable confidence (Wigley et al. 1984; Briffa 1995). EPS gauges the quality of the mean chronology and is dependent upon the mean correlation coefficient (RBAR) of the series and the sample size. The RBAR had a value of 0.198. The standardized chronology spans

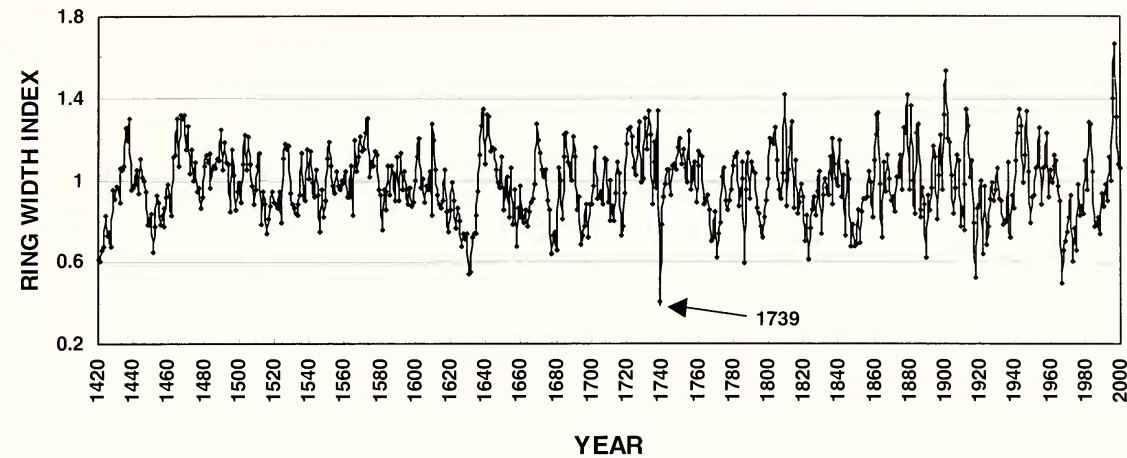


FIG. 3. Port Orford cedar standardized tree-ring chronology from A.D. 1420 to 2000 for the Page Mtn. study area in the Siskiyou Mountains of southwestern Oregon and northern California. The chronology is standardized around the mean index of 1.0. The year 1739 is indicated.

580 years of radial growth (A.D. 1420 to 2000) (Fig. 3). This dataset can be accessed via the International Tree-Ring Data Bank (ITRDB) at <<http://www.ngdc.noaa.gov/paleo/treering.html>> under the site name Page Mountain.

Climate/Growth Relationships

Tree-ring growth was negatively and significantly correlated with temperature of June ($r = -0.428$, $P < 0.001$), July ($r = -0.204$, $P = 0.037$), and the previous June ($r = -0.249$, $P = 0.011$; Fig. 4A). Growth was positively and significantly correlated with the temperature for the previous December ($r = 0.233$, $P = 0.017$) and the December before that ($r = 0.192$, $P = 0.051$). Precipitation for the current June ($r = 0.330$, $P < 0.001$) and previous December ($r = 0.272$, $P = 0.005$) show significant, positive correlations with ring width (Fig. 4C). Precipitation for the current May ($r = 0.162$, $P = 0.097$), previous May ($r = 0.278$, $P = 0.004$), and previous June ($r = 0.164$, $P = 0.095$) show positive correlations with the growth index. The Pearson tests showed significant, positive correlations between radial growth and PDSI for all months from the current September through the previous February (Fig. 4E). The strongest correlations were for the current June ($r = 0.421$, $P < 0.001$) and July ($r = 0.425$, $P < 0.001$).

Considering that the months of the current June and the previous December both have strong correlations for temperature and precipitation, we calculated the Pearson correlations between these months to test for possible autocorrelation of conditions among these summer and winter months. Neither precipitation ($r = 0.123$, $P = 0.212$) nor temperature ($r = 0.151$, $P = 0.125$) showed a significant relationship between June and December. Likewise, exploration of possible correlations between conditions of months of concern in sequen-

tial years did not show significant correlations for either temperature or precipitation. The correlations for annual conditions revealed significant relationships for PDSI ($r = 0.418$, $P < 0.001$) and precipitation ($r = 0.300$, $P = 0.002$) but not for temperature ($r = -0.007$, $P = 0.943$).

1739 Extreme Event

The year 1739 represented the lowest ring width index of the entire 580-year Port Orford cedar chronology at the Page Mtn. study site (Fig. 3). For this standardized chronology, the year 1739 had a ring width index of 0.408 in relation to the mean index of 1.0 ($SD = 0.358$). This low index value coincides with the striking visually distinctive damage that occurs on many cores after the latewood of 1738 and into the springwood of 1739 (Fig. 2).

In the entire Page Mtn. study site, 53.5% of the 271 cedars old enough to capture the 1738/1739 rings showed physical damage and the average growth index of 1739 was 0.601 (Table 2). Although sample sizes were too small in one watershed to perform statistical comparisons among watersheds, the growth index for 1739 was consistently below average for all watersheds and physical damage was evident in all watersheds with a range of 34.1 to 100% of cedars showing damage (Table 2). Physical damage to the 1738/1739 rings occurred in cedars across all geomorphologies (range 47.1–63.6%) and the proportion of trees exhibiting damage did not differ significantly between geomorphic categories ($\chi^2 = 1.96$, $df = 5$, $P = 0.853$). The growth index was consistently below average with a range of 0.519 to 0.615 in all geomorphic categories. There were no significant differences in growth index between geomorphic categories ($H = 3.56$, $df = 5$, $P = 0.614$).

Cedars at all regional sites, except for Horse Mtn., showed physical damage to the 1738/1739

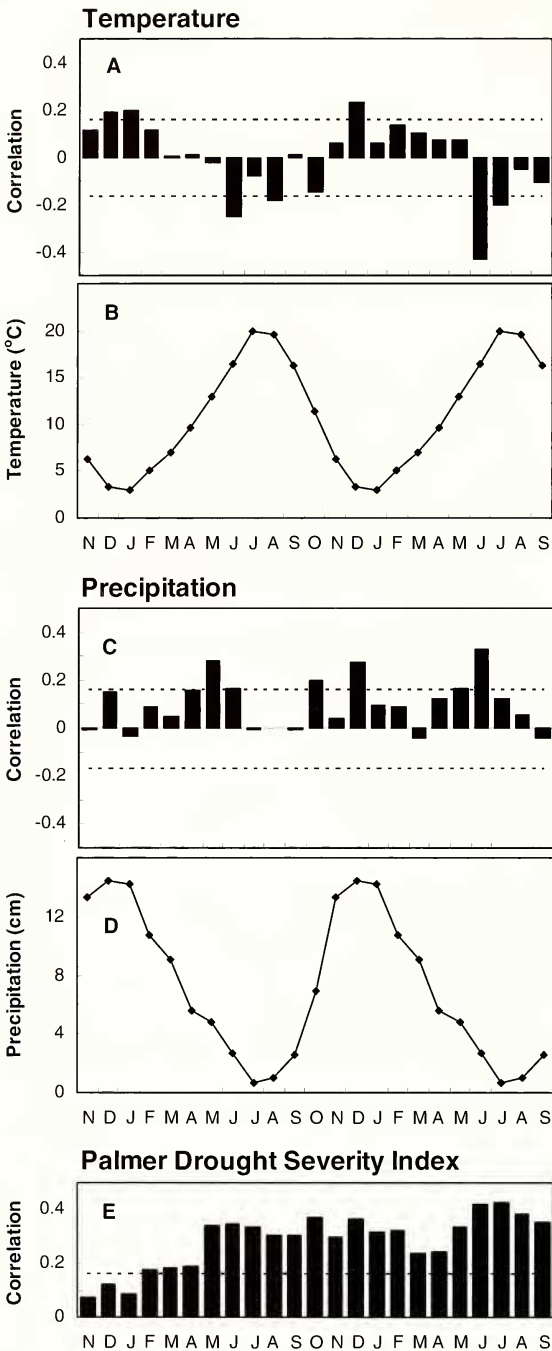


FIG. 4. Pearson correlation coefficients between tree-ring width index and mean monthly A) temperature, (C) precipitation, and (E) PDSI. Graphs B and D show the mean monthly temperature and precipitation, respectively. Climatic data are from the NCDC's Oregon Climate Division 3, spanning from A.D. 1895 to 2000. The horizontal line at 0.165 indicates the critical value ($\alpha = 0.05$).

ring, ranging from 12.5 to 76.9% of the trees sampled. Similarly, the growth index for the 1739 growth ring was below the average of 1.0 for all regional sites, except for Horse Mtn.

DISCUSSION

Climatic Implications

Tree-ring based climatic investigations generally focus on site and species specific conditions where tree-ring growth is known to be limited by a particular climatic factor, allowing for that signal in the growth rings to be maximized (Fritts 1976). Although the Page Mtn. dataset was originally sampled to reconstruct the infection history of *P. lateralis* on Port Orford cedar, the quality of the dataset prompted the creation of the chronology and investigation of the relationship of cedar growth and relevant abiotic factors. The validity of this chronology and crossdatatability of Port Orford cedar is supported by the high COFECHA series correlation for the master chronology and the correlation statistics for the standardized chronology, specifically the Expressed Population Signal (EPS). With a quality, responsive chronology in a region that has very few climatic studies and for a species with no known tree-ring chronologies, this study provided important baseline information on both regional climate and species-specific responses.

Our analyses revealed information about which climatic parameters control the radial growth of Port Orford cedar at our main study site in the Siskiyou Mountains (Fig. 4). The consistent, positive correlations for PDSI indicate the importance of soil moisture availability for all months of the year. These results correspond with the geographic distribution of Port Orford cedar being limited to areas that maintain significant soil moisture year-round (Zobel et al. 1985). The annual average of PDSI showed a strong correlation with radial growth, emphasizing the long-term effects of moisture supply for the cedar's growth. Similarly, the analysis for the annual average of precipitation indicates that the cedar has increased growth during wet years. The insignificant relationship for annual temperature reflects the opposite signs of the significant correlations for summer and winter months.

In summer, the Siskiyou Mountains experience hot and dry conditions that are shown here to limit growth of the Port Orford cedar. Specifically, the month of June showed a strong, negative correlation for temperature and a strong, positive correlation for precipitation, indicating the importance of this month for cedar growth. Little et al.'s (1995) analysis of *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir) growth in the Siskiyou Mountains shows similar results for the month of June. Significant negative correlations for July temperature most likely also reveal the limiting effect of summer temperature on moisture, and thus for the radial growth of Port Orford cedar. For PDSI, June and

TABLE 2. SUMMARY RESULTS FOR THE PHYSICAL DAMAGE AND GROWTH INDEX INDICATORS OF AN EXTREME CLIMATIC EVENT IN 1738/1739. Watershed and Geomorphology categories are for data within the Page Mountain study site.

	Physical damage		Growth index		
	% with damage	Sample size	Growth index	SD	Sample size
Page Mountain	53.5	271	0.601	0.257	264
Watershed					
Elder Creek	56.0	141	0.617	0.244	136
Little Elder Creek	60.0	65	0.532	0.265	65
Page Cree	55.0	20	0.726	0.238	20
Dunn Creek	100.0	4	0.420	0.077	4
Poker Creek	34.1	41	0.619	0.279	39
Geomorphology					
Active channel	47.1	17	0.568	0.258	17
Streambank	59.8	82	0.609	0.252	79
Floodplain	52.8	36	0.572	0.306	33
High floodplain	50.0	20	0.566	0.238	19
Terrace	55.6	9	0.615	0.290	9
Hillslope	63.6	22	0.519	0.203	22
Regional					
Page Mountain	53.5	271	0.601	0.257	264
Coquille River Falls	76.9	13	0.613	0.464	12
South Fork Smith River	50.0	4	0.732	0.265	4
Bluff Creek at Fish Lake	60.0	5	0.878	0.393	5
Clear Creek	46.2	13	0.710	0.277	13
South Fork Sacramento River	12.5	16	0.847	0.388	16
Horse Mountain	0.0	3	1.109	0.298	3

July are the months with the highest correlations, underscoring the significance of summer soil moisture conditions. A positive correlation for precipitation for both the current and previous May reflect the effect of spring precipitation at the beginning of the growing season when higher temperatures may induce greater transpiration and water use. In summary, our results are in agreement with other studies that have shown the importance of soil moisture for conifer growth in the Pacific Northwest (Robertson et al. 1990), especially during the late spring and summer (Waring and Franklin 1979; Brubaker 1980).

Winters in the Siskiyou Mountains are typified by cool, mediterranean conditions. Our analysis revealed that Port Orford cedar growth is responsive to wet conditions and elevated soil moisture in winter but prefers warmer winter temperatures. Specifically, the month of December showed the strongest correlations. In regards to a growth affinity for warm winter temperatures, our results are similar to Douglas-fir studies in the Siskiyou Mountains (Little et al. 1995) and the Pacific Northwest as a region (Peterson and Heath, 1990). However, unlike Douglas-fir, which can be inhibited by wet conditions in the winter (Little et al. 1995), Port Orford cedar responds positively to wet conditions and soil moisture even in the winter. This may reflect the greater number of pathogens that utilize Douglas-fir (e.g., needle casts), where wet winters may aid in pathogen growth and reproduction (Scharpf 1993). Port Orford cedar has few known pests or

pathogens due to its high volatile oil content and *P. lateralis* is the only pathogen known to cause mortality (Zobel et al. 1985).

Overall, we find radial growth of Port Orford cedar at Page Mountain promoted by high year-round soil moisture, cool and wet conditions in summer (June), and warm and wet conditions in winter (December). With much of southern Oregon and northern California experiencing hot, dry summers, many Port Orford cedars are limited to riparian regions that provide them with required levels of soil moisture (Zobel et al. 1985). Because the cedars sampled for this chronology were originally used to reconstruct the invasion of a water-born disease, this chronology is composed of cedars found in relatively moist, highly infectable areas. While the trees used in our study are representative of the majority of the cedar's population within the study area, creating a chronology from cedars found in more sensitive areas (e.g., drier, upland sites) may allow for a stronger signal to be recognized.

Extent and Potential Cause of the 1738/1739 Climatic Event

The year 1739 was likely affected by anomalous climatic conditions as evidenced by 1739 showing the smallest ring width index for the entire 580-year chronology as a single-year departure from the common pattern (Fig. 3). In over half the cedars with inner-ring dates pre-1739 (Table 2), there was physical damage in the form of abnormal cells and

discoloration to the 1738/1739 ring. Often, deposits of resin extend from after the latewood of 1738 into the earlywood of 1739, pinpointing a trauma event occurring in the dormant season after the 1738 growth season or during the early growing season of 1739. At the Page Mtn. site, the spatial extent of this event was consistent across all five watersheds and across topographic position relative to the stream.

Evidence of the 1738/1739 event in the form of physical damage and below average growth index was found at all of the regional sites sampled except for Horse Mtn. With Horse Mtn. having the fewest trees sampled ($n = 3$) of our regional sites, it is possible that the conditions of the event occurred there but we did not sample a tree that recorded it. It is also possible that the event did not affect this site, perhaps because of its southernmost position among our sampled sites. Frequency of occurrence varied among the sites; however, sampling was not sufficient for evaluating intersite differences in the event's severity. Rather than comparing sites, our intention was to document the occurrence of the event across Port Orford cedar's range. We conclude that the 1738/1739 event did occur on a scale that approximates a large portion of the cedar's range.

In a precipitation reconstruction from drought-sensitive conifers, Graumlich (1987) classified 1739 as a severe, single-year drought for the Pacific Northwest as a whole, with a strong signal for the southern extent that overlaps with the range of Port Orford cedar. That low soil moisture availability (PDSI) and low precipitation have been shown to limit the radial growth of Port Orford cedar and that 1739 is the smallest ring of the entire chronology support the classification of 1739 as a severe, single-year drought for the current study. This extends the range of the 1739 severe, single-year drought event initially classified by Graumlich to include a more western extent. Knapp et al. (2002) examined tree-ring records from *Juniperus occidentalis* spp. *occidentalis* Hook. (western Juniper) to classify extreme, single-year drought events in the interior Pacific Northwest using climatic pointer years from A.D. 1500 to 1998. Although it was not among the top 50 published drought years, the year 1739 ranked 67th (13th percentile) for all sites sampled in this study (Knapp personal communication). This further supports the classification of 1739 as a severe, single-year drought event for the Pacific Northwest, including the southwestern extent captured by the range of Port Orford cedar. A drought reconstruction in central Oregon (Pohl et al. 2002) and tree ring records of precipitation in eastern Oregon (Keen 1937) did not show 1739 as an extreme year, suggesting that the event did not produce a strong signal in areas further inland.

While a below average ring width index for 1739 is ubiquitous for Graumlich (1987), Knapp et al. (2002), and our current study, this year is unique

for Port Orford cedar in regards to the physical damage found in cedars across its range. Here, we examine the potential cause of this trauma event. Considering that the event affected Port Orford cedars throughout the range of the species, a fire of such scale would be recognizable in other tree-records of the area. The lack of such evidence discounts fire as a possible cause (Taylor and Skinner 2003; Skinner personal communication 2003). Dendrochronological records show an outbreak of heart rot in western juniper in the Pacific Northwest occurring between 1730 and 1749; however, damage to the cedars indicate a strong single-year event, not a multi-year event (Knapp and Soulé 1999). Furthermore, there are no known diseases or pests that can significantly suppress radial growth in Port Orford cedar. The invasion by the fatal pathogen *P. lateralis* was not occurring prior to 1952 (Hansen et al. 2000).

Another potential cause for the damage is a regional freezing event. During a freeze, tissues contract and can cause the crushing of cambial cells and the formation of a frost ring (Glerum and Farrar 1966). LaMarche and Hirschboeck (1984) linked the formation of frost rings with the cooling effect created from stratospheric aerosol veils produced from volcanic eruptions. Although a major volcanic eruption occurred in 1739 on Mt. Tarumai (Shikotsu) on the Japanese island of Hokkaido, this eruption has been dated after the spring of 1739, excluding it as a cause of the damage to the cedars (Simkin and Siebert 1994). The possibility of a regionally extending frost event, independent of volcanic activity, is still a consideration for the cause of the damage to the cedars.

That the strongest physical damage of the cedar chronology coincides with the smallest ring width index (severe, single-year drought) presents the possibility that the trauma event was linked to drought conditions. Although the drought is evident in the growth ring for 1739, the conditions likely existed in the dormant season prior to growth. Injury could occur in the winter or early spring if, for example, replenishment of water deficiencies is prevented by a prolonged frost (Larcher 1980). Such an event is sensible considering that much damage to Port Orford cedars occurs in dry, windy, cold weather, where desiccation is a key parameter (Zobel et al., 1985). Although the cause of the 1739 physical damage is inconclusive, we believe that the most likely cause is a frost event coupled with a dry year.

SUMMARY

We have created a quality, responsive chronology for Port Orford cedar in the Siskiyou Mountains of southwestern Oregon and northern California that spans from A.D. 1420 to 2000. This dataset represents the first standardized tree-ring chronology established for Port Orford cedar and shows

this species to be suitable for dendroclimatological studies. The radial growth of Port Orford cedar was correlated with soil moisture availability year-round that corresponds with the cedar's distribution. Hot and dry summer conditions in the Siskiyou Mountains were both found to limit the cedar's growth. Port Orford cedar growth showed an affinity for warm winter temperatures, as other studies have found to be true for Douglas-fir in the Siskiyou Mountains. However, unlike Douglas-fir, the cedar was responsive to wet winter conditions, emphasizing the cedar's strong dependence on soil moisture year-round. The year 1739 consistently showed a small ring width and physical damage to the earlywood for cedars across the spatial extents of the Page Mtn. site and also across most of the range of the cedar. The conspicuously small size of the 1739 growth ring has been linked to a single-year, severe drought that affected the Pacific Northwest. This study extends the range of this drought to include the southwestern portion of the Pacific Northwest that is represented by Port Orford cedar. The trauma event represented by the physical damage was pinpointed to have occurred in the dormant winter season of 1738 or during the early spring of 1739 and is possibly indicative of a frost event associated with the weather conditions of a drought year.

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